GALILEO VIEWS OF CRUSTAL DISRUPTION ON EUROPA. R. Sullivan[1], M. Belton[2], K. Bender[1], M. Carr[3], C. Chapman[4], R. Greeley[1], J. Head[5], K. Homan[1], J. Moore[6], R. Pappalardo[5], B. R. Tufts[7], and the Galileo SSI Team. [1]Department of Geology, Arizona State University, Tempe, AZ 85287-1404; [2]NOAO, Tucson, AZ; [3]USGS Menlo Park, CA; [4]Southwest Research Institute, Boulder, CO; [5]Brown University, Providence, RI; [6]NASA-Ames, Moffett Field, CA; [7]Lunar and Planetary Laboratory, Tucson, AZ.

Voyager and Galileo images show the surface of Europa to be criss-crossed with a variety of lineaments indicative of tectonic activity. A particularly prominent zone of crustal disruption marked by complex patterns of dark bands in brighter plains was seen by Voyager in limited 2 km/pixel coverage [1]. Dark, wedge-shaped bands [2] seen in this area were interpreted as "pull-apart" zones that divide icy crustal plates which have rotated and moved relative to one another [3,4,5,6]. New examples of these features were observed at 1.6 km/pixel during Galileo's first orbit (G1), and a subset of features seen by Voyager 2 were targeted at 420 m/pixel during Galileo's third orbit (C3). Galileo G1 images show this style of tectonism extends WSW from the area viewed by Voyager to the western limit of G1 coverage (about 20S,240W). Although suitable coverage for the entire zone has not been obtained yet, it is clear that this style of tectonism is not centered at the anti-jovian point. Dark bands within this zone are up to 35 km wide. Contacts between the dark band materials and bright plains units generally are sharp, in contrast to the diffuse margins of triple bands [7]. Sharp contacts allow shape comparisons between opposing margins of each band, revealing close matches in many instances. This indicates relative translation and rotation (generally <5 deg) between icy plates across areas now filled with dark band materials. Reconstruction of bright plates into pre-fractured configurations by dispensing with intervening dark material can be accomplished with little to no overlap of plate margins, but reconstruction also reveals that a small fraction of bright plains material is missing, and has somehow been consumed or altered (i.e., darkened).

Not all dark lineaments in the zone of dark-banded crustal disruption seen in G1 coverage are expressions of crustal tension and rifting. Dark bands with diffuse edges that superficially resemble triple bands for short segments are also present. Diffuse margins of these bands make reconstruction of some plate configurations less certain. Reconstruction of one particularly complex area at 14S,216W indicates a sequence of plate rifting that was followed by rotation and closure with a component of right-lateral faulting. The compression zone is a dark band, but has a diffuse margin similar to triple band margins.

Little internal structure can be seen within the dark bands in the G1 1.6 km/pixel coverage, but many band interior details are visible in 420 m/pixel data obtained on orbit C3. On this orbit a small section of dark, wedge-shaped bands first seen by Voyager 2 were targeted under low sun illumination to emphasize morphological information. The most prominent dark band seen in this image has (1) interior lineaments that are parallel to band margins and each other, (2) a central lineament pair, (3) axial symmetry of some features (e.g., mirrored arrangements of prominent internal lineaments and pits), and (4) age/brightness relationships similar to triple bands (i.e., the largest dark bands brighten to background terrain levels with increasing age - but the sample is small). Narrower dark bands lack many or all of these internal features, and have neutral or positive relief. Reconstruction across the most prominent dark band in the C3 data, at 17S,197W, involves movement of at least 20 individual bright plates. The northern 75 km of the feature can be closed by about 18 km of ENE-WSW translation. The southern 105 km of the feature can be closed by rotations of about 9 degrees around a pivot point located at 21S,195W. Two other band systems, each with parallel lineaments in their interiors, can be closed with average plate translations of about 17 and 20 km.

Interior features of the most prominent dark band seen in the 420 m/pixel C3 data are consistent with repeated emplacement of dike materials at the center of the feature only, with material moving to each side to make way for newer material. Lineaments closer to the center trace a less jagged version of the sharp margin shape. This could indicate that the original fracture determined where new material was initially emplaced, but as spreading continued the emplacement process and material characteristics gradually imposed their own, probably more efficient, configuration. If this inference is correct, a scale of 10+ km could be significant in the process by which band material rose to the surface. Sharp, matching contacts between bands and bright plate materials, even at 420 m/pixel, preserve the shape of the original fracture opening, and this is consistent with low lateral mobility - perhaps high viscosity - of the dike material during emplacement episodes. The dark bands with matching sharp margins provide good evidence for crustal spreading in these areas, but there is no clear evidence yet of corresponding zones where significant amounts of bright plate material might have been consumed contemporaneously with plate rifting. The close fit obtained when bright plates are reassembled implies that their shapes and surface areas have remained relatively constant during rifting, so features analogous to major subduction zones should not be expected within the bright plates. The possibility that dark bands might at times alternate as sites of crustal compression and consumption cannot be ruled out.

Reassembly of bright plates by dispensing with intervening dark material and fitting plate margins together results both in restoring and destroying feature matches across plate boundaries. This implies emplacement of dark band materials occured contemporaneously with formation of smaller ridges and other features within the bright plates themselves. (At Voyager and G1 resolution formation of dark bands might appear as almost the last tectonic events to influence the bright plains, but this is an artifact of resolution. Higher resolution shows ridge formation continued to occur within the bright plates.) The close fitting reassembly of bright plates, as well as indications that ridge formation continued to occur after intervening dark band material was emplaced, imply that ridges within the bright plates represent primarily vertical displacements of pre-existing crust, not lateral emplacements of new material like the dark bands. Some ridges locally have similar brightness characteristics to the dark bands they cross. This, too, is consistent with some ridges being composed primarily of pre-ridge surface materials that have been displaced upward several tens of meters. Alternatively, if these ridges form volcanically, then the source materials must be shallow enough to closely correspond to surface albedo patterns.

The most prominent (≥10 km wide) dark bands with sharp margins are 75 to 150 km apart. Groups of bright plates between these features apparently have moved as units in association with crustal spreading at these bands, resulting in about 10-15% extension across the severely disrupted zone seen in the G1 coverage. Least compressive stresses are ENE-WSW in the area of 10S,200W, and NNW-SSE in the area of 10S,235W. Where these two trends intersect, at about 20S,225W, dark band patterns are especially complex. One possibility is that the distribution and spacing of prominent dark bands reflects the organization and movement of ductile material beneath the brittle icy crust. Specifically, the band locations where material rose to fill voids associated with rotation and translation of 75-150 km diameter plate groups reflects the dimensions of what may have been localized, poorly developed convection cells of about half this diameter. (A water ice-rich layer ~50 km thick is allowed by several analyses that assume differentiation and segregation of water from a deeper silicate mantle [8,9]).

Alternatively, plate fracturing and movement in response to regional surface stresses simply allowed passive rise of material to the surface. Clues to a possible source of regional stress become more apparent when image data are reprojected centered on 40S,205W, an area seen indistinctly by Voyager 2 that appears to be very densely fractured. Surrounding this area is a belt of bright plains with prominent darker bands showing evidence for plate offsets [3,4,5,6,10,11] - including the disrupted zone seen in G1 coverage and the pull-apart bands seen at higher resolution on C3. Perhaps destruction of crust in the area of 40S,205W by localized heating or impact caused tensile stresses that resulted in the plate offsets seen by Voyager and Galileo. Some support for plate movements driving the creation of dark bands (instead of the other way around) comes from the observation of plate offsets and pull-aparts in areas without a regularly spaced grid of bands or of plate groups. A feature seen in G1 coverage at 52N,230W transitions from a pair of curvilinear, narrow, wedge-shaped dark bands 250 km long in the west to a narrow ridge extending several hundred km to the east. The wedge-shaped band pair can be closed with about 1 degree of reconstuctive rotation near the band-to-ridge transition, implying a compressional origin for the ridge extending to the east. Better resolution and illumination would be helpful in confirming the nature of this feature, but if the interpretation here is correct, some linear or curvilinear ridges seen elsewhere could also have a compressional origin. Other, subtle examples of surface feature offsets in the northern bright plains seen in G1 data do not seem to be part of an organized grid of regularly-spaced bands, and this suggests that creation of new icy crust by plate spreading is more a function of surface stresses causing fractures that are exploited by ductile sub-crustal materials, and that organized convective overturn in ductile materials below the crust is not required.

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